Frontiers of Dynamical Systems

Fission-Fusion Dynamics and Social Behavior in Bats Community

Amir E. BozorgMagham
Yuan Lin

Dr. Nicole Abaid
Dr. Shane Ross

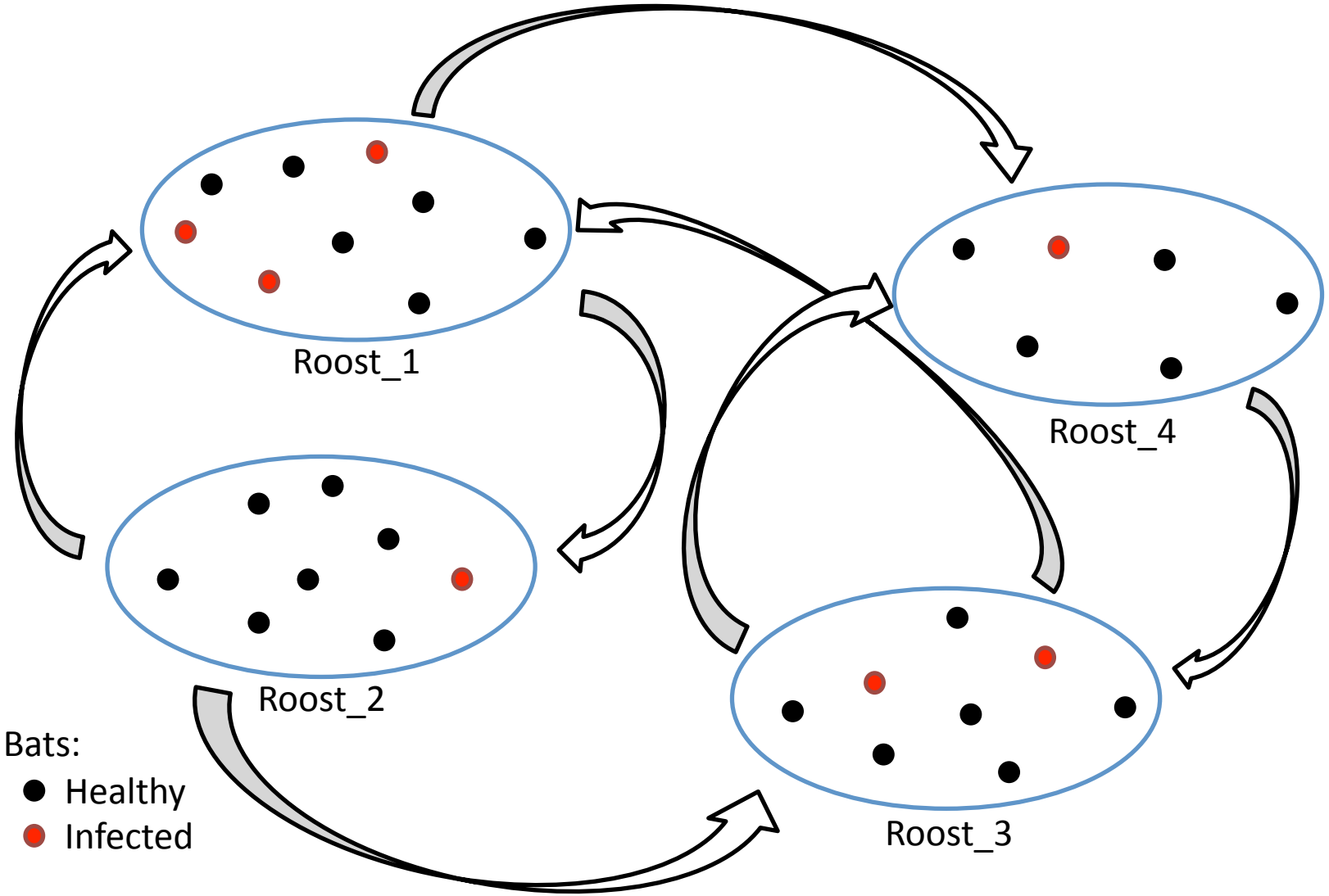
Fission-Fusion Dynamics

- Balance of maximized individual benefits and minimized costs,
  - Benefits: temperature, avoiding predators, stream of data, energy efficiency, …
  - Costs: lack of food, diseases, limited space, …



- How: social dynamics, a time varying system that follows SIMPLE rules on the individual scale and shows complex behavior on the group scale:
  - Fission: dividing or splitting,
  - Fusion: joining together.

Fission-Fusion Dynamics, Bats community



Fission-Fusion Dynamics,
Bats community

- ***Kashima model***: balancing the conflicting needs of maximizing information accuracy and minimizing infection risk.
  - Each roost has a constant quality.
  - Each individual bat has its estimation of some other roosts,
  - Each bat communicate with all the roost mates.
  - An infected bat recover at a constant probability rate,
  - Each bat has a random error of estimation.

Bat Roost-switching Behavior in Kashima's Model

Parameter setting:

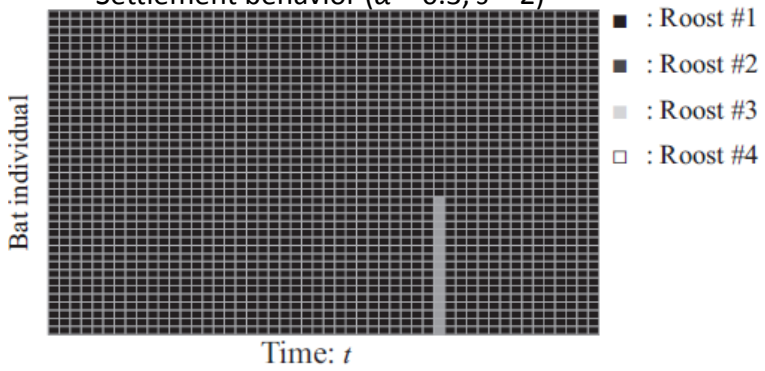
- Number of bats: $N = 40$
- Number of roosts: $J = 4$
- Quality of roosts: $j = 10, 9, 8, 7$
- Gaussian-distributed noise in roost quality estimation:
  - mean: $m = 0$
  - standard deviation: s
- Learning rate: α, $(0 < \alpha < 1)$
- Degree of uncertainty in decision making: $\beta = 15$

s and α vary to obtain different bat roost-switching behavior.

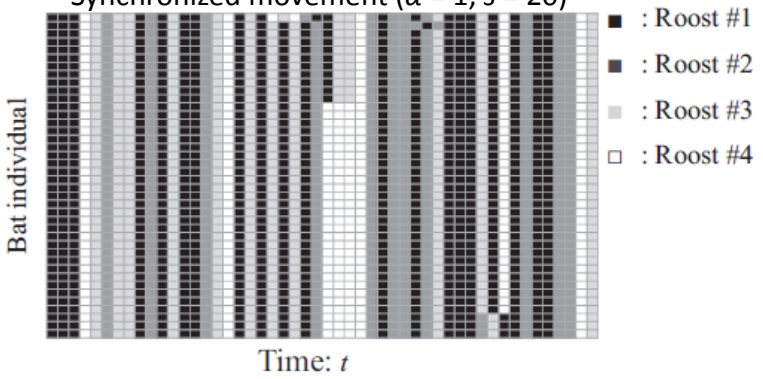
Bat Roost-switching Behavior in Kashima's Model

- Settlement behavior
- Synchronized movement
- Fission-fusion behavior

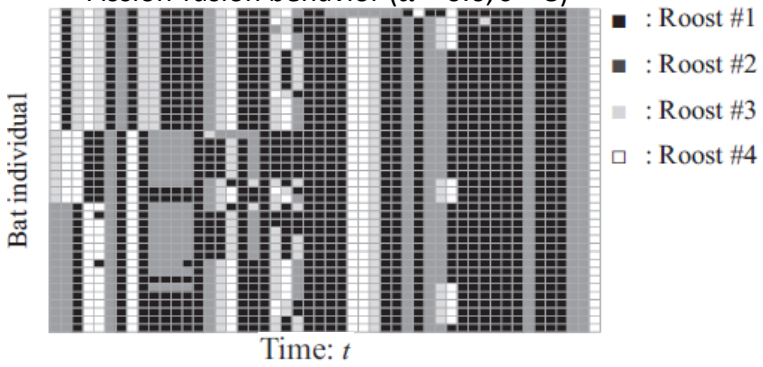
Settlement behavior (α = 0.3, s = 2)



Synchronized movement (α = 1, s = 20)



Fission-fusion behavior (α = 0.6, s = 8)



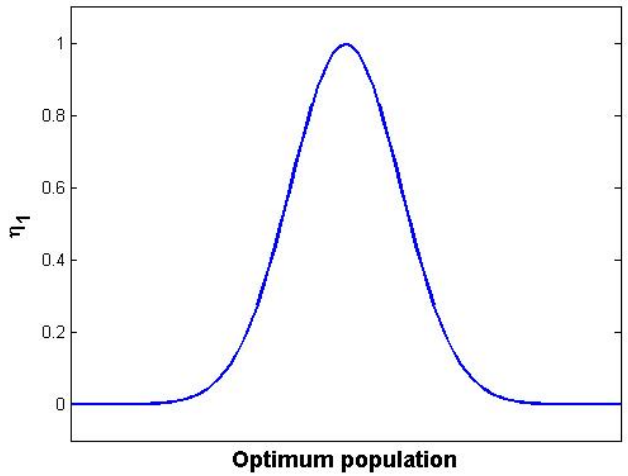
Fission-Fusion Dynamics, Bats community

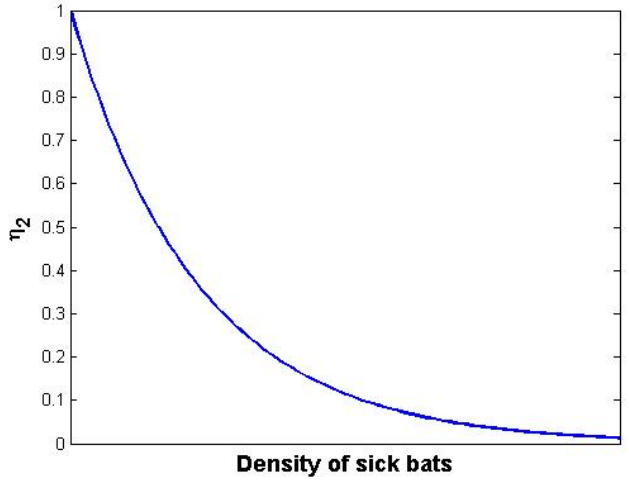
- ***Possible modifications:***
  - Roost quality is a function of population, density of infected bats and inherent condition of a roost,
  - Each individual communicates randomly with some roost mates,
  - Each individual will update its knowledge about the other roosts based on its experiences and communication results,
  - Becoming sick or healthy depends on the population of sick bats,
  - Each bat has a random error of estimation about its living roost,
  - Random error of estimation is higher for short term visit.

Two specific examples of modifications

Dynamic quality of a roost

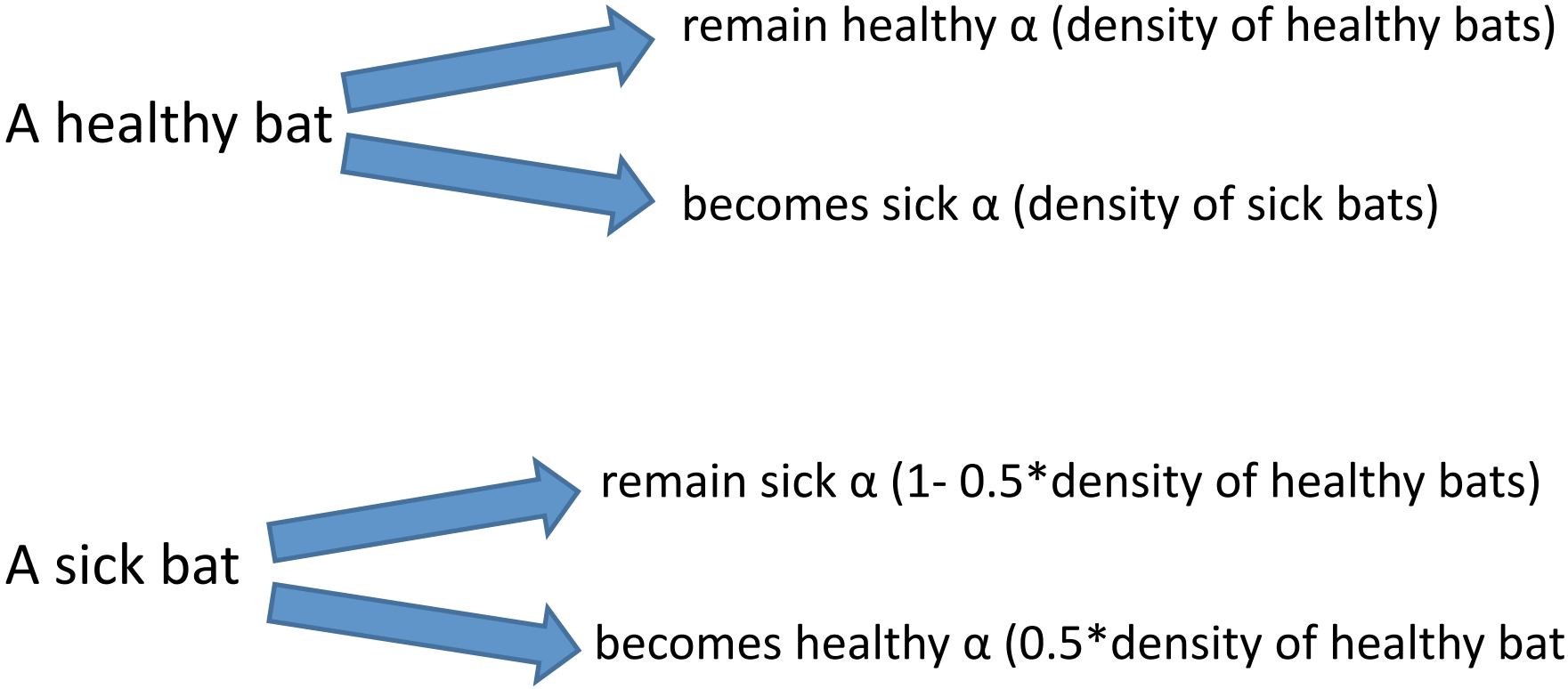
- Roost quality is a function of:
  - Population: η_1
  - density of infected bats: η_2
  - inherent condition, e.g., ventilation: η_3
  - $\mu = \eta_1\, \eta_2\, \eta_3$





Two specific examples of modifications

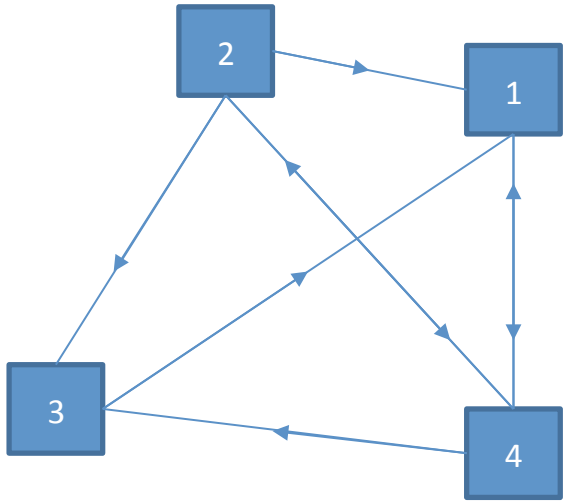
Dynamic propagation of disease



Graph Theory to Study Social Network

A graph contains nodes and edges (directed and undirected).

- Adjacency matrix, *A* (connections between nodes).
- Out-degree matrix, *D* (number of connections originating at each node).
- Graph Laplacian, $L = D - A$.



$$A = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 \end{bmatrix} \quad D = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 3 \end{bmatrix}$$

$$L = D - A = \begin{bmatrix} 1 & 0 & 0 & -1 \\ -1 & 3 & -1 & -1 \\ -1 & 0 & 1 & 0 \\ -1 & -1 & -1 & 3 \end{bmatrix}$$

Evaluation of Fission-fusion Behavior Using Network Properties

Network properties	Corresponding measurements in bat fission-fusion behavior
Minimum number of spanning trees	Number of roosts where bats stay
Degree centrality	Degree of fusion in bat roosting behavior
Betweenness centrality	Information sharing or disease spreading between bats
Clustering Coefficient	Degree of friendship or probability of infection